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Determination of palatal rugae patterns among two ethnic populations of India by logistic regression analysis

Vijayalakshmi S. Kotrashetti MDS Dr, Reader [a,*], Kiran Hollikatti MDS Dr, Post Graduate Student [a], M.D. Mallapur M Sc Statistician [b], Seema R. Hallikeremath MDS Dr, Prof. and Head [a], Alka D. Kale MDS Dr, Professor [a]

[a] Department of Oral Pathology and Microbiology, KLE VK Institute of Dental Sciences and Hospital, Nehru Nagar, Belgaum 590010, Karnataka, India
[b] Department of Community Medicine, JN Medical College, Belgaum 590010, Karnataka, India

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ABSTRACT

Palatal rugae patterns are relatively unique to an individual and are well protected by the lips, buccal pad of fat and teeth. They are considered to be stable throughout life following completion of growth, although there is considerable debate on the matter, they can be used successfully in post mortem identification provided an antemortem record exists. Thus the aim of this study was to examine palatal rugae shape among two Indian populations and determine the accuracy in defining the Indian population using logistic regression analysis.

The study comprises two groups from geographically different regions of India with basic origin from Maharashtra and Karnataka state. The sample includes 100 plaster cast equally distributed between two populations and genders with age ranging between 18 and 40 years. Impression of maxillary arch was obtained using alginate impression material and plaster cast was made. The rugae was delineated on the cast using a sharp graphite pencil under adequate light and magnification and recorded according to classification given by Kapali et al. and Thomas and Kotze (1983).

Chi-Square analysis showed significant difference in wavy, circular and divergent pattern between the two populations. The straight and wavy forms were significant in logistic regression analysis. A predictive value of 71% was obtained in determining the original cases correctly when straight, wavy, curved and circular patterns were assessed. 70% of predictive value was achieved when all rugae patterns were assessed. Mean number of rugae was greater in females compared to males with straight pattern showing statistically significant difference between males and females.

Significant difference was recorded among straight, wavy, circular and divergent pattern between two populations. Consequently this study demonstrates moderate accuracy of palatal rugae pattern using logistic regression analysis in identification of Indians.

1. Introduction

Palatoscopy is the study of palatal rugae pattern in order to establish the identity of a person. In the recent decade palatoscopy has gained its importance in forensic odontology.[1] Post mortem identification using teeth is relevant in population who posses teeth, but in certain situation where teeth are lost or a person is edentulous, identification becomes difficult. In such cases palatal rugae can be used as an alternative adjunct in forensic identification.[2,3]

Palatal rugae are irregular, asymmetrical ridges present on the anterior palate just behind the incisive papillae on either side of the median palatine raphe. The rugae are well protected by the lips, buccal pad of fat and teeth, thus survive post mortem insults.[1,4] Studies have shown that rugae pattern are unique to an individual[5,6] and have been equated with fingerprints.[7] Effect of thermal changes on palatal rugae has been studied and it is noted that the changes in them are less pronounced as compared to the generalize state of the victim with pan facial three degree burns.[8] Furthermore they can resist decomposition changes for up to seven days after death.[1] Palatal rugae pattern remain stable throughout an entire person's life following completion of growth. Additionally it has been reported that they retain their stability even during orthodontic treatment and extraction of teeth.[9]

* Corresponding author. Tel.: +91 9448929312; fax: +91 0831 2470640.
E-mail address: drviju18@yahoomail.com (V.S. Kotrashetti).

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Therefore palatal rugae can be an important identification feature in forensic science and can be used in post mortem identification provided an antemortem record exists. In addition, significant association between rugae forms and ethnicity has been determined by various authors.[10]

Previously, identification of different population using palatal rugae was done by recording both dimension and rugae pattern, until Thomas and Kotze observed the difficulties in classifying and interpreting the smallest and limitless variation in rugae pattern and emphasized the necessity to standardize the procedure. They concluded that a universally acceptable classification is impossible and suggested that a single operator alone using his own classification can successfully apply in identification of person, comparison of this result is important and not the classification.[11–13] Shetty SK et al., Preeti N et al. and Vishelish A et al. have observed significant difference among two Indian populations by using rugae shapes.[10,14,15] Hence we sought to study palatal rugae shapes between two different Indian populations, to determine its effectiveness in identifying the populations correctly using logistic regression analysis. This may have relevance in odonto-stomatological identification in India, where data regarding dental anthropology and odontology is negligible.

2. Materials and methods

The study was carried out among two groups from geographically different regions of India. The groups were divided based on their linguistic differences as well as ethnicity i.e. Maratha who were basically from Maharashtra and speak Marathi, Lingayat who were basically from Karnataka and speak Kannada. The sample included 100 plaster cast equally distributed between the two populations and genders. The age groups included were between 18 and 40 years because studies have shown no change in rugae pattern once growth is completed.[10] Subjects who underwent orthodontic treatment, treated for cleft palate and any other palatal pathology were excluded from the study. Institutional ethical clearance was obtained for conduct of study.

After obtaining informed consent from the subjects alginate impression of the maxilla was obtained and plaster casts were made (Chromatic alginate impression material-tropicalgin of Zhermack clinical company with batch number LOT-93521 was used for impressions and VIP stone plaster (yellow) manufactured by Vensons India with batch number 02400 was used for plaster cast). The rugae were delineated using sharp tip HB pencil on the cast under adequate light by single person. The rugae pattern was recorded according to Kapali et al.[16] as wavy, curved, straight, circular (Fig. 1a and b) and according to Thomas and Kotze[11] as Unification/branching further classified as diverging or converging depending on the type of origin (Fig. 1b). Any other form which did not fit into the criteria was classified as non-specific. In the present study all rugae shapes were considered irrespective of their length according to Preeti N et al.[10] Rugae observations were repeated by same observer and also different observer to rule out intraobserver and interobserver variability for 60 casts.

Association between rugae shape and ethnicity, rugae shape and gender were tested using Chi-square analysis. Intraobserver and interobserver agreement was analysed by Kappa statistics. Logistic regression analysis (LRA) was carried out to define the ethnicity using the SPSS version 10.0 statistical package.

LRA is used for multiple variables which can handle both discrete and continuous variables successfully. In LRA co-efficients and constants are derived and the variables are multiplied with the respective co-efficient and added to the constant. It results in log-odd or log-it. A predictive probability (p), which falls between 0 and 1, can be derived from the log-it using the function. $p = 1/1 + e^{-y}$, where y is the log-it of the multiple regression equation, i.e., $y = a + b_1x_1 + b_2x_2 + \cdots b_nx_n$. The default cut-off in logistic regression is 0.5, where a person with $p < 0.5$ is classified into Maharashtra and $p > 0.5$ is classified into Karnataka state. The closer the value is to 1, the greater the probability that the case belongs to Karnataka, while a value closer to 0 indicates a greater probability of the case belongs to Maharashtra.

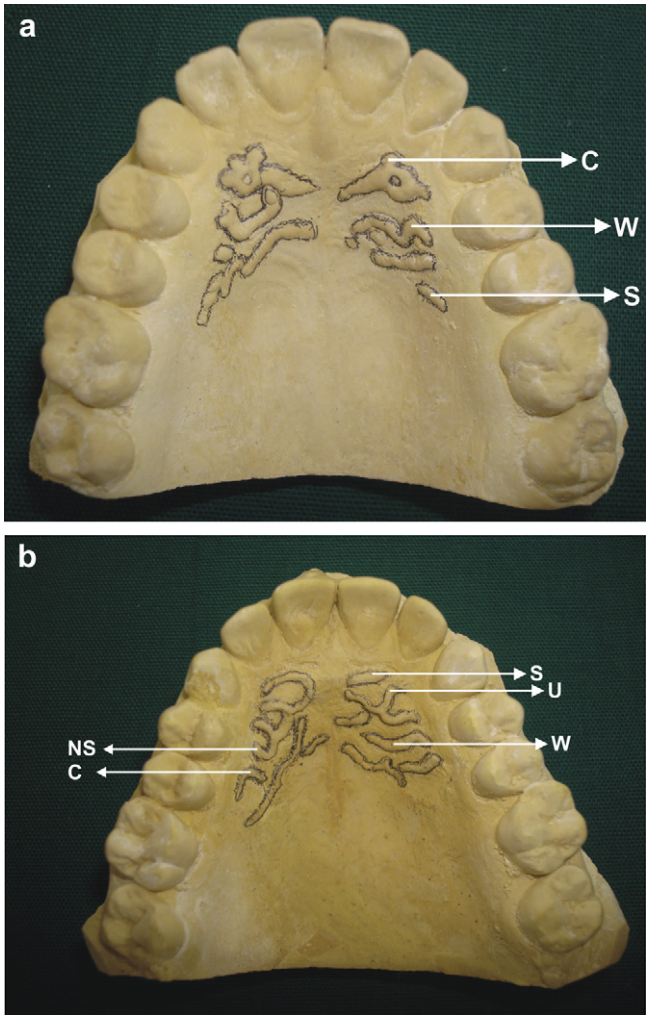


Fig. 1. (a) and (b): Different types of palatal rugae shape delineated in maxillary casts. S – Straight, C – Curved, W – Wavy, U – Unification, NS – Non-Specific.

Subsequently cross-validation of the predicted accuracy of the original population was done. Cross-validation is used to predict the performance of a model on a validation set using computation in place of mathematical analysis. The method followed was K-fold cross-validation. In K-fold cross-validation, the original sample is randomly partitioned into K sub samples, of the K sub samples (100 casts) a single sub sample is retained as the validation data for testing the model, and the remaining K – 1 sub samples (100 – 1 = 99casts) are used as training data. The cross-validation process is then repeated K times, with each of the K sub samples used exactly once as the validation data. The K results from the folds then is averaged to produce a single estimation.

3. Results

The percentage of occurrence of different rugae shapes in the groups is described in Table 1. The mean rugae number in

Table 1
Frequency and median of different rugae shapes in Karnataka and Maharashtra state population.

Sl. No	Rugae pattern	Maharashtra			Karnataka		
		M	F	Percentage (%)	M	F	Percentage (%)
1	Straight	59	95	154 (27.5%)	48	68	116 (21.48)
2	Wavy	113	99	212 (37.85%)	134	123	257 (47.59)
3	Curved	62	65	127 (22.67%)	49	59	108 (20.0)
4	Circular	–	4	4 (0.71%)	5	2	7 (1.30)
5	Non-Specific	3	3	6 (1.07%)	5	2	7 (1.30)
6	Converging	–	4	57 (10.17%)	–	1	45 (8.33)
7	Diverging	25	28		22	22	
	Total	262	298	560 (100%)	263	277	540 (100%)

Table 2
Kappa statistics for assessing intraobserver agreement in recording different rugae shapes.

Sl. No	Group	Variables	Kappa statistics	*P* value
1	Maharashtra	Straight, wavy, curved circular, non-specific	0.99	< 0.001
		Only unification	0.99	< 0.001
2	Karnataka	Straight, wavy, curved and circular	0.99	< 0.001
		Only unification	0.99	< 0.001

Table 3
Kappa statistics for assessing interobserver agreement in recording different rugae shapes.

Sl. No	Group	Variables	Kappa statistics	*P* value
1	Maharashtra	Straight, wavy, curved, circular and non-specific	0.78	< 0.001
		Only unification	0.83	< 0.001
2	Karnataka	Straight, wavy, curved and circular	0.71	< 0.001
		Only unification	0.86	< 0.001

P value < 0.001 – Significant (S) and *P* value > 0.001 – Non-Significant (NS).

Maharashtra was greater compared to Karnataka. The more prevalent forms in both groups were straight and wavy, followed by curved. Few circular and non-specific rugae forms were also recorded. Unification amounted to be 10.17% in Maharashtra and 8.33% among Karnataka population. Straight type was more in number among Maharashtra and wavy type was more in number among Karnataka (Table 1). Kappa statistics showed good agreement between intraobserver and interobserver variability (Tables 2 and 3).

Chi-Square analysis showed significant difference in wavy, circular and divergent pattern between the two groups (Table 4). Similarly Chi-square analysis done to assess the sexual dimorphism showed significant difference in straight pattern (Table 5). Females (575) had greater number of rugae than males (525) (Table 1).

Table 4
Chi-square analysis for assessing difference in rugae shapes between Karnataka and Maharashtra state population.

Sl. No	Variables	Chi-square value	Degree of freedom	*P* value
1	Straight	11.791	6	0.067 (NS)
2	Wavy	21.035	7	0.004 (S)
3	Curved	3.925	6	0.687 (NS)
4	Circular	5.415	1	0.020 (S)
5	Non-Specific	2.990	1	0.084 (NS)
6	Converging	0.260	1	0.609 (NS)
7	Diverging	12.630	3	0.006 (S)

P value < 0.05 – Significant (S) and *P* value > 0.05 – Non-Significant (NS).

Table 5
Chi-square analysis for assessing sex differences in rugae pattern.

Sl. No	Variables	Chi-square value	Degree of freedom	*P* value
1	Straight	21.112	6	0.002 (S)
2	Wavy	6.162	7	0.521 (NS)
3	Curved	10.098	6	0.120 (NS)
4	Circular	5.415	1	0.538 (NS)
5	Non-Specific	0.379	1	0.564 (NS)
6	Converging	2.343	1	0.126 (NS)
7	Diverging	5.878	3	0.118 (NS)

P value < 0.05 – Significant (S) and *P* value > 0.05 – Non-Significant (NS).

Table 6
Showing regression co-efficient of all variables.

Sl. No.	Variables (x)	Regression co-efficient (b)	*P* value
1	Straight	−0.386	0.037 (S)
2	Wavy	0.351	0.020 (S)
3	Curved	−0.025	0.881 (NS)
4	Circular	0.557	0.350 (NS)
5	Non-Specific	1.168	0.094 (NS)
6	Converging	−1.064	0.347 (NS)
7	Diverging	0.065	0.823 (NS)
	Constant (a)	−0.817	

P value < 0.05 – Significant (S) and *P* value > 0.05 – Non-Significant (NS).

LRA was done for curved, wavy, straight, circular shapes without unification, and also combination of all shapes. Only straight and wavy forms were statistically significant (Table 6). A predictive value of 71% was obtained in determining the original cases correctly when only curved, wavy, straight and circular shapes were assessed (Tables 8 and 9), whereas 70% of predictive value was achieved when all rugae shapes were analysed (Tables 6 and 7). Statistically significant straight and wavy form were assessed for predictive value, only 63% of the original cases were correctly classified (Table 10). The estimated probability obtained for all the parameters showed $p < 0.5$, suggesting natives of Maharashtra and $p > 0.5$ natives of Karnataka (Histograms 1–3).

In the present study cross-validation was done for all variables and for curved, wavy, straight and circular shapes without unification as we obtained better predictive accuracy in these variables. The LRA accuracy in population identification is presented in (Tables 11 and 12). We obtained an accuracy of 71% when all shapes were used which is slightly higher than that of the original results, whereas the accuracy was 70% when only straight, curved, wavy and circular shapes without unification was considered the accuracy value was slightly lower than that of the original results. Cross-validation is mainly a theoretical construct and not a true accuracy; it gives a more realistic indication of the precision of the analysis used.

4. Discussion

Palatal rugae develop as localized regions of epithelial proliferation and thickening. Fibroblasts and collagen fibers then accumulate in the connective tissue beneath the thickened epithelium

Table 7
Predicted value to determine the two different populations using all variables.

Sl. No.	Actual group	Predicted value		Total No.	Correct percentage
		Maharashtra (50)	Karnataka (50)		
1	Maharashtra	33	17	50	66%
2	Karnataka	13	37	50	74%
3	Over all				70%

Table 8
Regression Co-efficient of curved, straight, wavy and circular without unification.

Sl. No.	Variables (x)	Regression co-efficient (b)	P value
1	Straight	−0.382	0.032 (S)
2	Wavy	0.342	0.016 (S)
3	Curved	−0.019	0.901 (NS)
4	Circular	0.637	0.299(NS)
5	Non-Specific	1.225	0.074 (NS)
6	Constant	−0.814	

P value < 0.05 − Significant (S) and P value > 0.05 − Non-Significant (NS).

Table 9
Predictive value using curved, wavy, straight and circular variables without unification.

Sl No.	Actual group	Predicted group		Total No.	Correct percentage
		Maharashtra (50)	Karnataka (50)		
1	Maharashtra	32	18	50	64%
2	Karnataka	11	39	50	78%
3	Over all				71%

Table 10
Predictive value using only straight and wavy which were significant with LRA.

Sl No.	Actual group	Predicted group		Total No.	Correct Percentage
		Maharashtra (50)	Karnataka (50)		
1	Maharashtra	31	19	50	62%
2	Karnataka	18	32	50	64%
3	Over all				63%

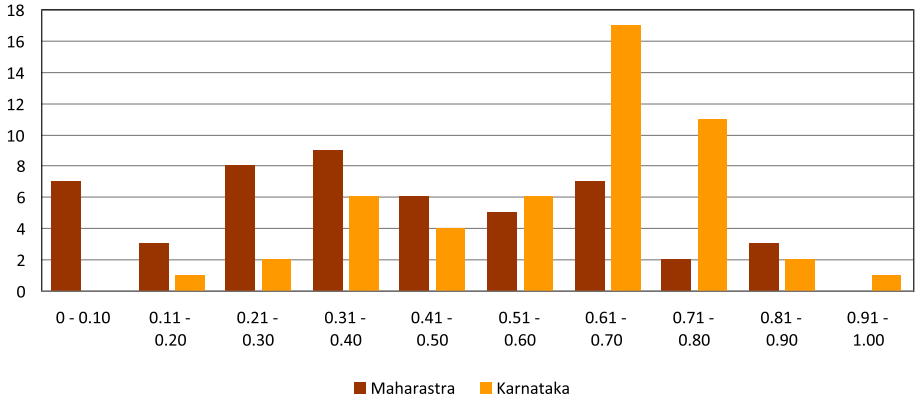
and assume distinct orientation. The fibers running anteroposteriorly within the core and in concentric curves across the base of each rugae determine their orientation.[17]

Its design and structure remain unchanged throughout life and can be used effectively in forensic sciences for person identification.[3] The most common methods of identification are visual, fingerprint and dental characteristics. Visual method is the best method to identify a person but in case of mass disasters it becomes difficult. Fingerprints have long been the standard identification process but antemortem records of fingerprints are often unavailable especially in cases involving fire, decomposition or massive trauma. Similarly, dental records may also pose problems like missing teeth in case of disaster, makes it difficult to identify the person. An ideal post mortem identifier is one that is present in all victims and is resistant to change. One such method used for identification is palatal rugae.[5] Thomas and van Wyk successfully identified a severely burnt edentulous body by comparing the rugae to those on the victim's old denture, indicating that rugae are stable in adult life.[8] Thus the present study was carried out to identify two Indian populations using rugae shapes. Previous studies have reported racial differences based on mainly the rugae dimensions (e.g. Some authors have considered rugae $\geq$5 mm).[11,15,18] The rugae dimensions may vary with growth, extraction of teeth or teeth movement and may be construed as continuous variables, while rugae shape remains stable and are discrete variables. Thus, differentiating genetically similar populations using continuous variables such as rugae measurements have its limitations.[10] Discrete variable such as rugae shape could provide better results.

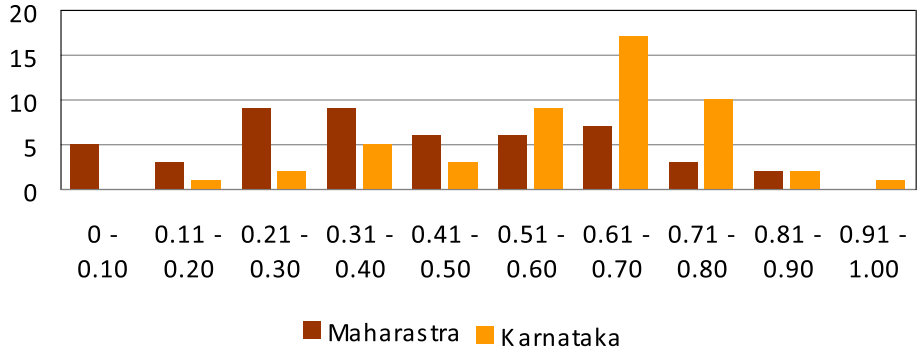
In the present study, we found mean rugae number to be greater in females compared to males which is in contrast to the findings of others.[16,15] We also noted significant difference in straight rugae pattern between males and females (Table 5). This suggests that observation of rugae pattern is a subjective process and it may not depict some of the more intricate rugae patterns but perhaps complex patterns induce observer errors.[10] Present study showed no significant intraobserver variability, ruling out subjective errors. Dokke and Osato reported females have fewer numbers of rugae than males and right side of the palate has greater number of rugae than the left side. These authors suggested that this was due to the phenomenon of regressive evolution dominating the right side of the palate and being more evident in female.[16] Similarly VH Venegas et al. found greater number of rugae in males than in females. Several other authors have found no statistically significant difference between male and female rugae pattern.[10,15,19] Thus further studies are required with larger sample size to determine the difference between males and females.

Among the two population studied the most common form seen was straight and wavy followed by curved pattern (Table 1). On Chi-square analysis wavy, circular and divergent pattern were more significant between two groups (Table 4). This result is in contrast to the results obtained by Shetty SK et al. where they compared rugae pattern among Mysorean and Tibetan populations and they reported curved form more common in the former and wavy form in the latter.[15] Similarly, Preeti N et al. and Kapali S et al. reported wavy and curved forms more common among two populations studied.[10,16]

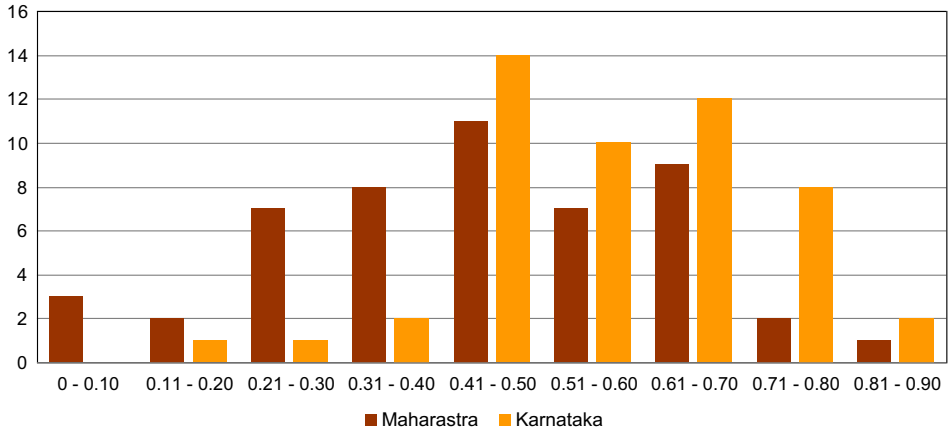
In this study divergent pattern showed significant difference using Chi-Square analysis which is in accordance with the study conducted by Vishilesh A et al. among Manipuri and Karnataka population. They noted straight and wavy shapes more prominent in both the group, with Manipuri population showing divergent pattern more when compared to Karnataka.[14] Also comparison of



Histogram 1. Estimated Probability using all variables in determining 2 populations.



Histogram 2. Estimated Probability using Straight, Curved, Wavy, Circular, without unification pattern in determining 2 populations.



Histogram 3. Estimated Probability using only straight and wavy pattern in determining 2 populations.

rugae patterns between African and European population revealed that the Africans had statistically greater numbers of unifications and circular rugae.[18] Preeti N et al. have also reported absences of circular pattern and unification being rare in their study group.[10] In our study we noted presence of all the patterns thus it suggests that rugae pattern specific for the population. We also noted some non-specific forms of rugae thus providing scope for further classification of rugae pattern.

Comparative studies showed definite variation in rugae pattern among different population groups but systematic trends in precise population determination are lacking specially among Indian population. Even though Preeti N el al. have derived a population specific equation by using discriminant analysis, but authors were of the opinion that use of non-parametric discriminant procedure would be ideal.[10] Hence to ascertain this we subjected rugae pattern to LRA. LRA can handle both discrete and continuous variables, which need not be normally distributed, linearly related or of equal variance within each group. It has been successfully used in forensic odontology in race determination and age estimation.[20] On literature search we found lack of data regarding application of LRA in determining the different populations using rugae pattern. Previously studies on rugae have been done using rugae dimensions and pattern. Rugae dimensions are continuous variables and rugae pattern is discrete variable. Population variations as such are on a continuous scale and the difference between geographically close and genetically similar group using continuous variables has its limitation. Thus discrete variables give better results. Furthermore rugae length, uniformly recordable in different populations may lack specificity for race categorization.[10] Thus LRA can handle multiple variables successfully in determining the populations.

In the present study straight and wavy were found to be statistically significant on LRA. Straight pattern was more common in Karnataka and wavy pattern being more common in Maharashtra (Table 6). LRA analysis showed that 70% of cases can be accurately classified into the original groups when all variables were analysed, whereas when only curved, straight, wavy and circular shapes were considered without unification the accuracy rate in determining the population was 71% (Tables 7 and 9). On analysis of statistically significant straight and wavy patterns for predictive value, only 63% of the populations were correctly classified into original group with probability being correctly determined (Table 10). LRA gave a jackknife accuracy of 71% when all variables were analysed whereas 70% was obtained when only curved, straight, wavy and circular shapes were considered without unification on cross-validation (Tables 11 and 12). Thus this study showed moderate to highest degree of accuracy in determining the two groups, analyzing all variables and also by using curved, straight, wavy and circular shapes without unification. Even estimated probability showed that $p < 0.5$ belongs to Maharashtra and $p > 0.5$ belongs to Karnataka state (Histograms 1–3).

Study by Shetty SK and Vishelish Arora et al. among two different Indian population found significant difference among the groups but did not determine the effectiveness of rugae pattern in

Table 11
Population identification accuracy of the LRA using all variables.

	Maharashtra	Percentage	Karnataka	Percentage	Total correct (%)
Original	33/50	66%	37/50	74%	70%
Cross-validation	33/50	66%	38/50	76%	71%

Table 12
Population accuracy of the LRA using curved, wavy, straight and circular variables without unification.

	Maharashtra	Percentage	Karnataka	Percentage	Total correct (%)
Original	32/50	64%	39/50	78%	71%
Cross-validation	31/50	62%	39/50	78%	70%

identification of population accurately.[14,15] Similar study by Preeti N et al among two Indian population reported jackknife accuracy of 70% by analyzing significant parameter, i.e. straight, curved and wavy pattern using discriminant function analysis.[10] Thomas and Kotze have analysed both dimension and pattern of rugae among six different South African populations and got accuracy of 25.3–72.2%, thus they stated that the race of an individual cannot be determined with certainty from the rugae but when they attempted to identify two genetically similar groups they got an accuracy of 61.8%.[12]

The present study examined two relatively similar groups and was able to obtain moderate but relatively higher accuracy using LRA. LRA analysis appears to be more significant because all variables can be used and better accuracy is obtained. Subsequently we believe that types of rugae pattern can be used as variables in determining different Indian populations and LRA differentiates Indian population with better accuracy. Greater weightage is given to unique feature in forensic identification and we believe that rugae shape is relatively unique to certain populations and have better utility in population differentiation provided antemortem records exist.

5. Conclusion

Palatoscopy is a technique that can be of great interest in human identification. It is unique to an individual and can be used successfully in population identification. In the present study it was found that LRA can moderately determine identification of specific population. Significant difference was recorded among straight, wavy, circular and divergent pattern between two populations. We even noted difference in sex showing significant difference in straight pattern using Chi-square analysis. Thus, these differences can be attributed to genetic factors and also recent shared ancestry has probably rendered these differences to moderate levels. Furthermore we would like to conclude that the sample size should be large and more number of Indian populations should be considered to determine the accuracy of palatal rugae in population identification. This is a preliminary study on genetically similar Indian population, where scope still exists for further study to determine gender as well as population identification. Finally we believe that rugae can be used as a reliable guide in forensic identification.

Ethical approval
None declared.

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Conflict of interest
None declared.

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